

WHAT IS CLAIMED IS:

1. A zoom lens, comprising in sequence from an object side:

a first lens unit having a positive optical power;  
a second lens unit having a negative optical power;  
a third lens unit having a positive optical power; and  
a fourth lens unit having a negative optical power,  
wherein the zoom lens executes zooming by moving all  
said first, second, third, and fourth lens units along an  
optical axis, and at least one of said first, second, third,  
and fourth lens units has at least one diffractive optical  
surface.

2. A zoom lens according to claim 1, wherein said  
diffractive optical surface comprises concentric circular  
phase gratings that are rotationally symmetrical with  
respect to the optical axis of said zoom lens.

3. A zoom lens according to claim 1, wherein at least  
one of said first lens unit and said fourth lens unit  
comprises said diffractive optical surface.

4. A zoom lens according to claim 1, wherein said  
first, second, and fourth lens units are individually

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denoted as the i-th lens unit, where i equals 1, 2, 3 or 4, and said first, second, and fourth lens units are collectively denoted as the entire i-th lens unit, wherein when the optical power obtained by the diffractive action of the diffractive optical surface of said i-th lens unit is denoted by  $\phi_{Di}$ , and the optical power of the entire i-th lens unit is denoted by  $\phi_{Li}$ , the condition  $\phi_{Di}/\phi_{Li} > 0$  is satisfied.

5. A zoom lens according to claim 1, wherein said first lens unit comprises one positive lens element and one negative lens element.

6. A zoom lens according to claim 1, wherein said second lens unit comprises one negative lens element.

7. A zoom lens according to claim 1, wherein said third lens unit comprises at least two positive lens elements and at least one negative lens element.

8. A zoom lens according to claim 7, wherein said third lens unit comprises a bonded lens.

9. A zoom lens according to claim 1, wherein said fourth lens unit comprises one positive lens element and two

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According to claim 1, the surface has a structure comprising gratings corresponding to positive indices.

According to claim 2, the surface corrects lateral aberrations.

The device, comprising a substrate, a first element; and a second element, is adapted to said optical system comprising:

- having a positive refractive index;
- having a negative refractive index;
- having a positive refractive index;
- having a negative refractive index;

The device executes zeroth, first, second, third, and fourth order diffraction.

At least one of said elements is at least one of said elements.

a fourth lens unit having a negative optical power,  
wherein the zoom lens executes zooming by moving all  
of said first, second, third, and fourth lens units along an  
optical axis, and at least one of said first, second, third,  
and fourth lens units has at least one diffractive optical  
surface.

13. A method of magnifying light from an object with a zoom lens comprising:

a first step of positively refracting light from the object with a first lens unit having a positive optical power;

a second step of negatively refracting the light positively refracted by said first step with a second lens unit having a negative optical power;

a third step of positively refracting the light negatively refracted by said second step with a third lens unit having a negative optical power;

a fourth step of negatively refracting the light positively refracted by said third step with a fourth lens unit having a negative optical power;

fifth step of forming an image of the object with light negatively refracted by said fourth step;

a sixth step of changing the magnification of an image of the object formed in said fifth step by moving all of said first, second, third, and fourth lens units along an optical axis; and

a seventh step of diffracting the light from the object with a diffractive optical surface on at least one of said first, second, third, and fourth lens units.

14. The method recited in Claim 13, wherein said

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seventh step is performed by a diffractive optical surface comprising concentric circular phase gratings that are rotationally symmetrical with respect to the optical axis of said zoom lens.

15. The method recited in Claim 13, wherein said seventh step is performed by a diffractive optical surface on at least one of said first lens unit and said fourth lens unit.

16. The method recited in Claim 13, wherein the first, second, third, and fourth lens units are denoted as the  $i$ -th lens unit, where  $i$  equals 1, 2, 3 or 4, wherein the first, second, third, and fourth lens units are collectively denoted as the entire  $i$ -th lens unit, and wherein the optical power obtained by the diffractive action of the diffractive optical surface of the  $i$ -th lens unit is denoted by  $\phi_{Di}$ , and the optical power of the entire  $i$ -th lens unit is denoted by  $\phi_{Li}$ , and wherein said first, second, fourth, and seventh steps are performed such that the condition  $\phi_{Di}/\phi_{Li} > 0$  is satisfied.

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17. The method recited in Claim 13, wherein said first step of positively refracting the light from the object with one positive lens element and negatively refracting the

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light from the object with one negative lens element.

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18. The method recited in Claim 13, wherein said second step comprises the step of negatively refracting the light with one negative lens element.

19. The method recited in Claim 13, wherein said second step comprises the steps of positively refracting the light with at least two positive lens elements and negatively refracting the light with at least one negative lens element.

20. The method recited in Claim 19, wherein said third step comprises the steps of positively refracting the light with the at least two positive lens elements bonded to each other and to the at least one negative lens element and negatively refracting the light with the at least one negative lens element.

21. The method recited in Claim 13, wherein said fourth step comprises the steps of positively refracting the light with one positive lens element and negatively refracting the light with two negative lens element.

22. The method recited in Claim 13, wherein said

seventh step comprises the steps of diffracting the light with materials having different refractive indices comprising laminated phase diffraction gratings composed of materials having different refractive indices.

23. The method recited in Claim 13, wherein said seventh step comprising the step of correcting lateral chromatic aberration of the image of the object formed in said fifth step and magnified in said sixth step that would otherwise occur by diffracting the light from the object with the diffractive optical surface.

Sub 02 24. A device for correcting lateral chromatic aberrations in a zoom lens during zooming comprising:

at least diffractive optical surface disposed on at least one of a first lens unit having positive optical power, a second lens unit having a negative optical power, a third lens unit having a positive optical power, and a fourth lens unit having a negative optical power disposed in sequence from an object to together constitute a zoom lens that executes zooming by moving all of the first, second, third, and fourth lens units along an optical axis, wherein the diffractive action of said at least one diffractive optical surface corrects lateral chromatic aberration of the zoom lens that occurs during zooming.

25. The device according to claim 24, wherein said at least one diffractive optical surface comprises concentric circular phase gratings that are rotationally symmetrical with respect to the optical axis of said zoom lens.

26. The device according to claim 24, wherein said at least one diffractive optical surface is disposed on at least one of the first lens unit and the fourth lens unit.

27. The device according to claim 24, wherein the first, second, third, and fourth lens units are individually denoted as i-th lens unit, where i equals 1, 2, 3, or 4, and the first, second, third, and fourth lens units are collectively denoted as the entire i-th lens unit, wherein when optical power obtained by the diffractive action of the diffractive optical surface of the i-th lens unit is denoted by  $\phi_{Di}$ , and the optical power of the entire i-th lens unit is denoted by  $\phi_{Li}$ , the condition  $\phi_{Di}/\phi_{Li} > 0$  is satisfied.

28. The device according to claim 24, wherein the first lens unit comprises one positive lens element and one negative lens element.

29. The device according to claim 24, wherein the

second lens unit comprises one negative lens element.

30. The device according to claim 24, wherein the third lens unit comprises at least two positive lens elements and at least one lens element.

31. The device according to claim 30, wherein the third lens unit comprises a bonded lens.

32. The device according to claim 24, wherein the fourth lens unit comprises one positive lens element and two negative lens elements.

33. The device according to claim 24, wherein said at least one diffractive optical surface has a structure formed by laminating phase diffraction gratings composed of materials having different refractive indices.

34. A method of correcting lateral chromatic aberration in a zoom lens having a first lens unit of positive optical power, a second lens unit having a negative optical power, a third lens unit having a positive optical power, and a fourth lens unit having a negative optical power, the zoom lens executing zooming by moving all of the first, second, third, and fourth lens units along an optical

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positively refracted with a first lens unit  
having a positive refractive power with at least one  
diffractive optical surface on the first lens unit;

positively refracted with a first lens unit having a positive refractive power and then negatively refracted by a second lens unit having a negative refractive power and then positively refracted by a third lens unit having a positive refractive power with at least one diffractive optical surface on the third lens unit; or

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